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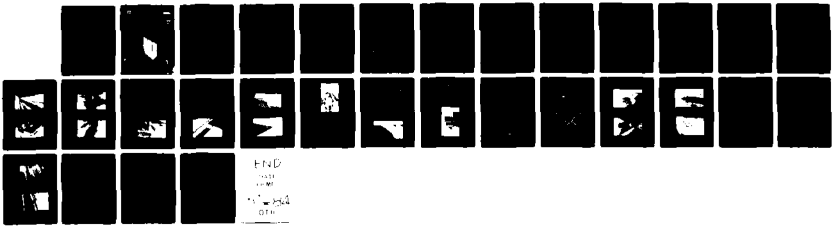

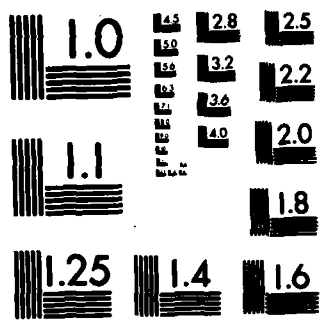

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INTERIM REPORT M-336
November 1983

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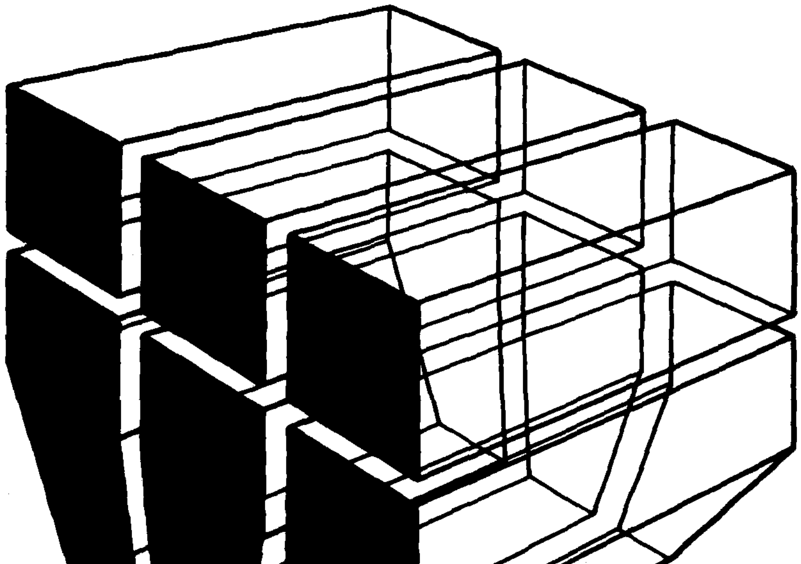
CONSTRUCTION OF ALUMINUM STANDING-SEAM ROOFING AT AN ARMY FACILITY

by
Myer J. Rosenfield



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4. TITLE (and Subtitle) CONSTRUCTION OF ALUMINUM STANDING-SEAM ROOFING AT AN ARMY FACILITY	5. TYPE OF REPORT & PERIOD COVERED FINAL
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Myer J. Rosenfield	8. CONTRACT OR GRANT NUMBER(s) Military Interdepartmental Purchase Request No. 81-938-16
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Construction Engr Research Laboratory P.O. Box 4005 Champaign, IL 61820	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE November 1983
	13. NUMBER OF PAGES 25
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

roofs
aluminum
Defense Construction Supply Center, Columbus, OH

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report documents the construction and instrumentation of an aluminum standing-seam roofing system on a Defense Logistics Agency warehouse. The condition and performance of the system are being checked and tested at periodic intervals to determine its behavior over annual cycles and to evaluate its capacity for long-term, trouble-free service.

This portion of the study observed the construction of the warehouse roof, including the specifications, materials, and building procedures used. Future studies will investigate

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the effects of corrosion on the aluminum panels and continue evaluations of temperatures and movement related to the system. The data will then be used to evaluate the roofing system's behavior over two annual cycles.

This type of system shows promise of being a good, long-lasting reroofing system for replacing deteriorated BUR, which is commonly used at Army installations. The contractor who installed the roof used good building practices, and these procedures can serve as a model for future installations of this type of roofing.

FOREWORD

This investigation was performed for the Defense Logistics Agency (DLA) by the Engineering and Materials Division (EM), U.S. Army Construction Engineering Research Laboratory (CERL). The work was performed under Military Interdepartmental Purchase Request No. 81-938-16 dated 17 August 81. Mr. Marvin U. DuBois was the DLA project monitor.

Appreciation is expressed to Mr. Gary Cattel of CTL Engineering, Inc., for monitoring the construction of the roof for Warehouse 8, and to Mr. Herbert Neff of the Ohio River Division, Corps of Engineers, and Mr. William Smith of the Facilities Engineer Office of the Defense Construction Supply Center, Columbus, OH, for their assistance. Mr. James Gambill and Mr. William Gordon of CERL made valuable contributions by designing and installing the instrumentation systems.

Dr. R. Quattrone is Chief of CERL-EM. COL Paul J. Theuer is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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FIGURES

FIGURES (cont'd)

CONSTRUCTION OF ALUMINUM STANDING-SEAM ROOFING AT AN ARMY FACILITY

1 INTRODUCTION

Background

Most Army facilities use conventional roofing systems, such as built-up roofing (BUR), that are sometimes expensive and complicated to construct. Such systems are often comparatively short-lived, resulting in high life-cycle roofing costs which are difficult for already over-burdened Army operation and maintenance budgets to absorb. Therefore, the Office of the Chief of Engineers asked the U.S. Army Construction Engineering Research Laboratory (CERL) to identify alternative, easy-to-install roofing systems that can improve the performance of Army roofing and reduce its life-cycle costs.

The Defense Logistics Agency (DLA) was preparing to install aluminum standing-seam roofing on three warehouses at the Defense Construction Supply Center (DCSC) at Columbus, OH. This roofing was to replace BUR which had been installed only 6 years previously. Being aware of CERL's roofing investigation program, DLA contacted CERL and the National Bureau of Standards (NBS) and requested that they monitor the construction and subsequent behavior of this roofing.

Objective

The overall objective of this project is to determine the behavior of aluminum standing-seam roofing over two annual cycles and evaluate the capacity for long-term, trouble-free performance. This report documents the construction and instrumentation of the roof system for one of the three DLA warehouses on which it was installed.

Approach of Overall Study

The following tasks were established to accomplish the work:

1. Observe and monitor the construction of the roofing on the warehouses (documented in this report).

2. Perform the following specific measurements and observations on the roofing every 6 months for 2 years:

a. Observe condition and performance of the roofing system at periodic intervals, and conduct required testing. This work would include checking each component, such as panel, flashing, ridge cap, etc., for corrosion, deformation, and movement.

b. Install gage points at appropriate locations to measure deformation and movement of the roof panel.

c. Check flashings carefully to make sure they perform as intended.

d. Measure temperatures of the metal roofing and the existing BUR with thermocouples.

e. Analyze panel samples at 6-month intervals to determine the extent and type of corrosion, using appropriate metallographic techniques such as microphotography, scanning electron microscope, etc. This task is being performed by the National Bureau of Standards (NBS).

f. Analyze and evaluate the results of these observations and measurements.

The results of the analysis and evaluation will be documented in a final report at the end of the study.

2 CONSTRUCTION

At a meeting in July 1981, copies of the plans and specifications were given to CERL and NBS for review. In October 1981, a preconstruction conference was held at DCSC in which comments from both agencies and all other details were discussed.

Under the contract, three warehouses were to be re-roofed: Nos. 8, 4, and 5, respectively (Figure 1). Each warehouse is 160 ft (48.8 m) wide by 1541 ft (470 m) long, and divided by firewalls into 11 approximately equal sections, each about 138 ft (42 m) long. Roofs are constructed with a slope of approximately 5/8 in. per foot (50 mm per meter). Roofing panels are 1 ft (300 mm) wide. With panels continuous from the central ridge to the eaves, each panel is 80 ft (24 m) long. Thus, there are about 3036 individual panels on each warehouse.

Because of the varied types of junctions and intersections which occur in the roofs, the contract specified that the contractor submit shop drawings for approval. In addition, the contractor submitted a model showing these various conditions full-size (Figure 2). This model was placed out-of-doors in an open location, so that it was readily available for reference.

Construction on Warehouse 8 began on 12 April 1982, and was monitored by CERL. The first operation was removing, by vacuum, all loose aggregate from the existing BUR (Figure 3). Sleepers of 4 x 4 in. (100 x 100 mm) treated lumber were installed into grooves cut into the BUR membrane and insulation on 5 ft, 8-in. (1.75-m) centers (Figure 4). Visible in the grooves shown in Figure 4 are shims which were used to ensure that the tops of the sleepers were elevated above the BUR surface to provide an air space between the BUR and the aluminum panels. The sleepers were screwed to the deck, which is a 2-in. (51 mm) tongue-and-groove wood plank.

The 80-ft (24-m) panel length is the longest standard length furnished by the manufacturer from the factory. Each panel is 1 ft (305 mm) wide, with a 2 1/2-in. (64-mm) roll-formed shape on each side. Figure 5 shows a cross section of the panel. Panels used at DCSC were .032 in. (.81 mm) thick. The sealant used was a 3/16-in.-(4.75-mm-) diameter butyl strip on a release paper. When placed as shown in Figure 6, it seals the standing seam and prevents entry of wind-driven or snow-melt water into the system.

The eave end of the seam was sealed with a foam rubber plug (Figure 7), applied before the seam was formed (Figure 8). This prevents entry of wind and water into the end of the seam.

After the panels were set in place (Figure 9), the ends of the seam were crimped with a hand tool (Figure 10), and the remainder of the seam locked with a traveling electric tool (Figure 11). The ridge ends of the panels were formed into a pan end, sealed with a closure that fills the panel from seam to seam, and then covered with a ridge cap (Figure 12).

Panels are retained in place by clips screwed to the sleepers. Each clip has bulbs at the top which fit into the seam and prevent the roof panels from lifting off while permitting expansion and contraction. There are two types of clips: one is for expansion, and one serves as an anchor (Figure 13). A button punch locks the panel seams to the anchor clips. These clips were placed at the two sleepers straddling the center of the panels, permitting expansion at both ends.

Figure 13 also shows the clip used along the firewalls to hold the edge of the first panel under the base flashing. A stepped aluminum counterflashing was installed (Figure 14) into reglets cut into the firewall parapet. Because of the high winds that can be expected in the Columbus, OH, area, a stainless steel strap was installed to provide uplift resistance to the counterflashing. Figure 15 shows flashing details. Figure 16 shows the intersection of counterflashings at the step, including the uplift resistance strap before it was bent up. The upper sheet was locked to the lower one by cutting a slit and locking the two pieces together as shown.

All this careful attention to detail, fabrication, and installation yields a roofing system which should provide many years of satisfactory service. The only deficiencies noted were related to design and installation of the ridge cap. On Warehouse 8, these occurred where the ridge cap intersected the flashings at the large central vents, and also occurs on all warehouses where the ridge caps ended at the firewall parapets.

The ventilator flashing intersection was detailed on the drawing shown in Figure 17. This shows a 5-in. (127-mm) vertical wall of the flashing, with the ridge cap low enough for the connection to be completely within this dimension. As shown in Figure 12, the vertical height of the ridge cap should be at least five times the expected roof movement. For 40 ft (12 m) of aluminum over a temperature range of −20°F (−29°C) to 120°F (49°C)–a difference of 140F° (78C°)–the expected change in length is about 7/8 in. (22 mm). Following the recommendation of Figure 12, the vertical height was set at 6 in. (152 mm). To fabricate the intersection as shown in Figure 18, the height of the vent flashing would have to be increased to more than the ridge cap. Instead, it was made equal to the ridge cap wall, and was actually fabricated to the 6-in. (152-mm) dimension. This made the intersection impossible to fabricate as detailed; the result is shown in Figure 19. A large amount of sealant was needed to waterproof these intersections.

The ends of the ridge caps at the parapets showed a similar deficiency. In one case, the peak of the ridge cap was very close to the top of the counterflashing (Figure 20). In another, the peak of the ridge cap was actually above the counterflashing (Figure 21). The picture shows the reglet into which the counterflashing

will be inserted, which has been primed with a black primer. Again, a great deal of sealant is used.

Neither of these details was addressed in the roof model. Figure 2 shows that the ridge cap was not included when the model was prepared. If it had been, these deficiencies would probably have become evident before the roofing components were fabricated.

Since these two ridge cap details depend greatly on the sealant to keep them watertight, they will have to be monitored very carefully to be sure that any deterioration of the sealant is repaired quickly and thoroughly.

3 TEST PROGRAM

One of the tests to be conducted on the roofing system is determining the effects of atmospheric corrosion on the aluminum panels; this study is being performed by NBS. A test rack containing 30 samples of the roofing material has been installed on one of the parapets of Warehouse 4 (Figure 22). These samples will be removed at 6-month intervals and analyzed to measure the rate and type of corrosion and to determine its effect on the material.

CERL has installed devices to measure temperatures and movement related to the system. Instrumentation was installed in the fifth bay from the north end of Warehouse 5, 37 ft (12 m) from the north end of the bay. Six stacks of thermocouples were installed, three each on the east and west sides of the warehouse (Figure 23). One thermocouple was attached to the lower surface of the roof deck to measure interior temperatures, one to the top of the existing BUR, and one to the top of the aluminum roof panels. Also, one thermocouple was mounted on an interior column near the switching box for all the thermocouples, and another thermocouple was mounted in an external shielded location to determine ambient temperatures. In all, 20 thermocouples were installed.

Elongation and deflection measurement points were established in the panel adjacent to the one with the thermocouples, but were placed 1 ft (305 mm) closer to the nearest firewall parapet. Figure 24 shows arrangements of these points.

Thermocouples were epoxied to the aluminum surface and covered with aluminized silicone sealant, as shown in Figure 25. Figure 26 shows a typical elongation and deflection measurement point.

This instrumentation was installed in July 1982, and initial readings were taken. Subsequent readings are being taken at 6-month intervals for 2 years, with the final ones in July 1984. These data will allow evaluation of the roofing system's behavior over two annual cycles.

4 DISCUSSION OF OBSERVATIONS

On the basis of observations made during monitoring of the construction, several features were noted that require careful monitoring over time:

1. **Foam Seals**. Foam rubber has a tendency to shrink and harden. This could cause leakage problems at the ridge closures and at the rib closure plugs. The rib closure plugs could be particularly troublesome, since they are not adhered to the rib, and could therefore fall out if shrinkage occurs. A driving rain could then penetrate under the panels, enter the cuts in the BUR made to install the sleepers, and leak into the building.

2. **Ice Dams**. Ice dams result when water from melting snow freezes on a cold overhang. Thus, water can build up over the level of the rib and seep through the seam if it is not sealed properly. If the butyl sealing strip used to seal the seams dries up, hardens, and cracks, the seam will be susceptible to leakage.

3. **Wind Uplift**. The system was installed with special features to guard against wind uplift damage (e.g. heavy-duty clips, counterflashing straps), so this should not be a problem. However, flashings and edgings should be checked periodically to ensure that these provisions were adequate.

4. **Corrosion**. The system was designed and installed to minimize corrosion problems from contact of dissimilar metals. To eliminate any sources of galvanic corrosion, all fasteners and accessories are made of either aluminum or stainless steel. The corrosive potential of the Columbus, OH, atmosphere is being monitored by NBS.

5. **Thermal Movement**. The theoretical thermal capabilities of the roofing system are excellent, since the panels are free to expand and contract longitudinally, and their cross section shape permits transverse

movement without inducing excessive stresses. Thermal response is being monitored for 2 years following installation of the instrumentation.

Special care is necessary during roofing design to ensure dimensional compatibility of all components. Metallic roofing cannot be formed in the same manner as single-ply membranes or sprayed polyurethane foam. Sometimes the only way design errors can be corrected in the field is with excessive use of elastomeric sealant, which is not supposed to be installed in thick applications. As this sealant ages, it cracks or splits; this will cause leaks to develop and allow water to enter the system.

5 SUMMARY

This report has documented the construction and instrumentation of an aluminum standing-seam roof system on a DLA warehouse. This type of system shows promise of being a good, long-lasting reroofing system for replacing deteriorated BUR, which is commonly used at Army installations. The contractor who installed the DLA warehouse roof used good building practices (see Chapter 2), and these procedures can serve as a model for future installations of this type of roofing.

Figure 1. Warehouse No. 8, DCSC.

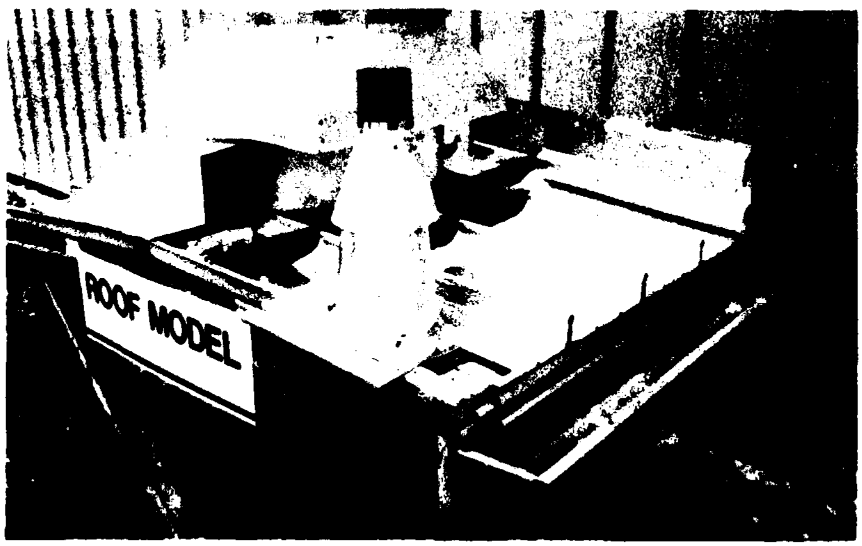

Figure 2. Roof model.

Figure 3. Vacuum removal of loose aggregate.

Figure 4. Installation of wood sleepers.

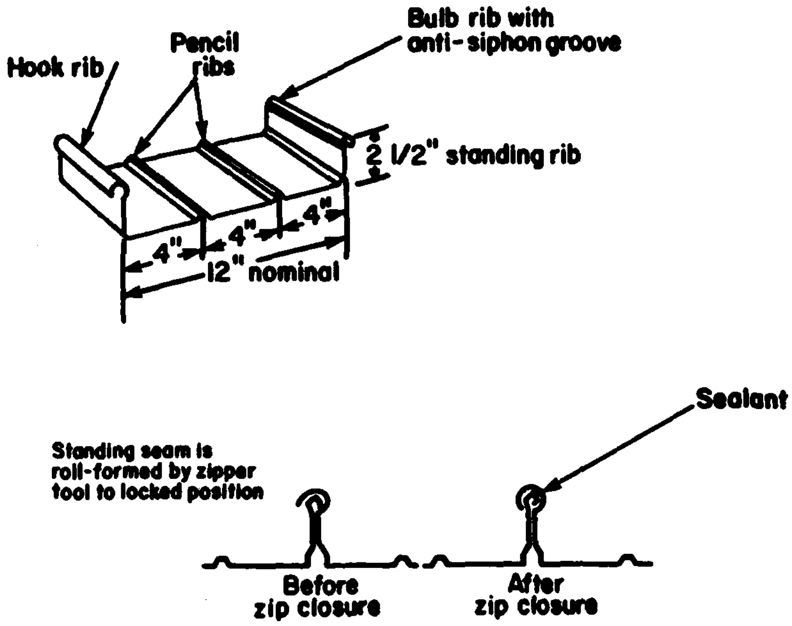

Figure 5. Detail of roofing panel.

Figure 6. Application of sealant.

Rib Closure

Cut from 1" foam rubber, this closure compresses to seal bulb rib and between legs of adjoining ribs.

Figure 7. Foam rubber rib closure.

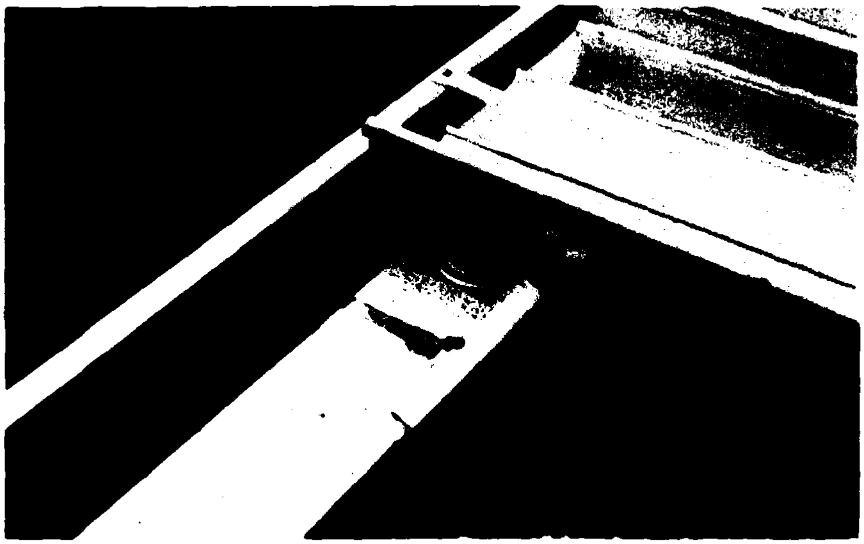

Figure 8. Rib closure in place prior to forming seam.

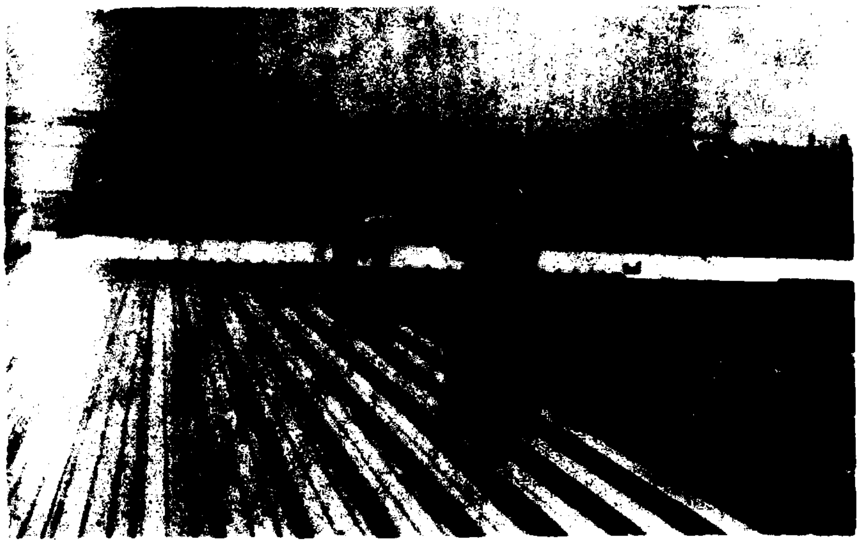

Figure 9. Placing aluminum panel.

Figure 10. Manual crimper for seam ends.

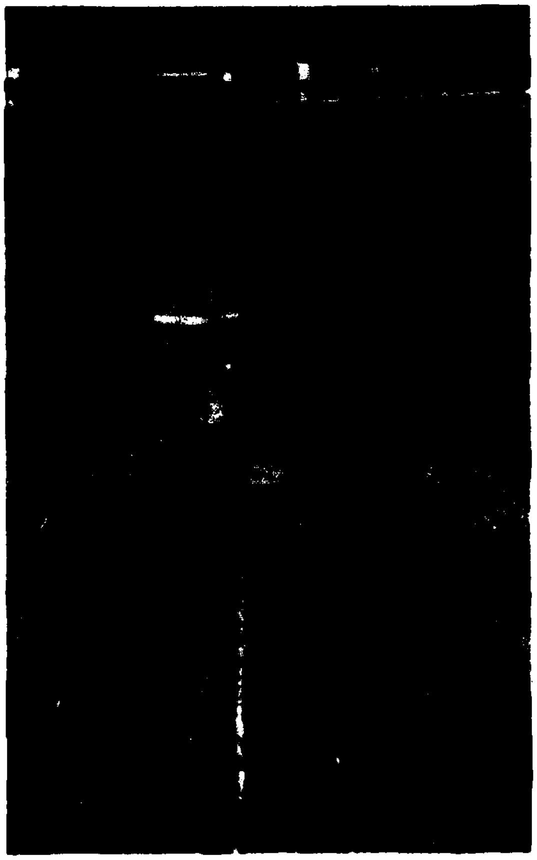

Figure 11. Electric seam lock tool.

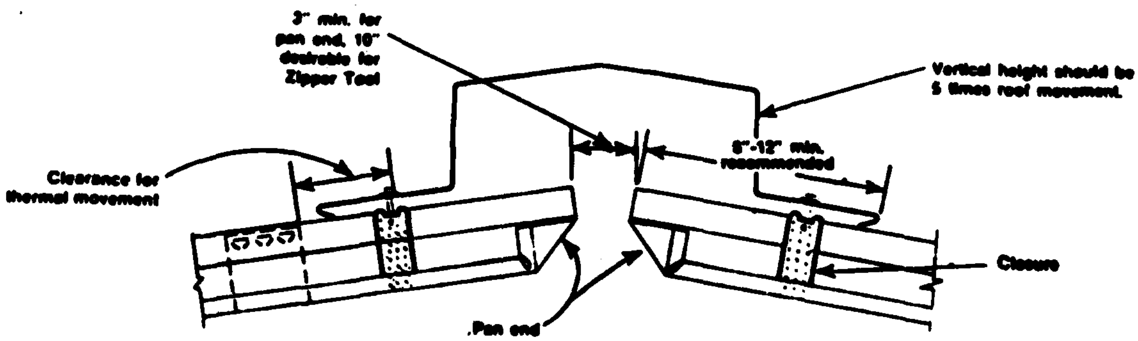

Figure 12. Ridge cap and end closures.

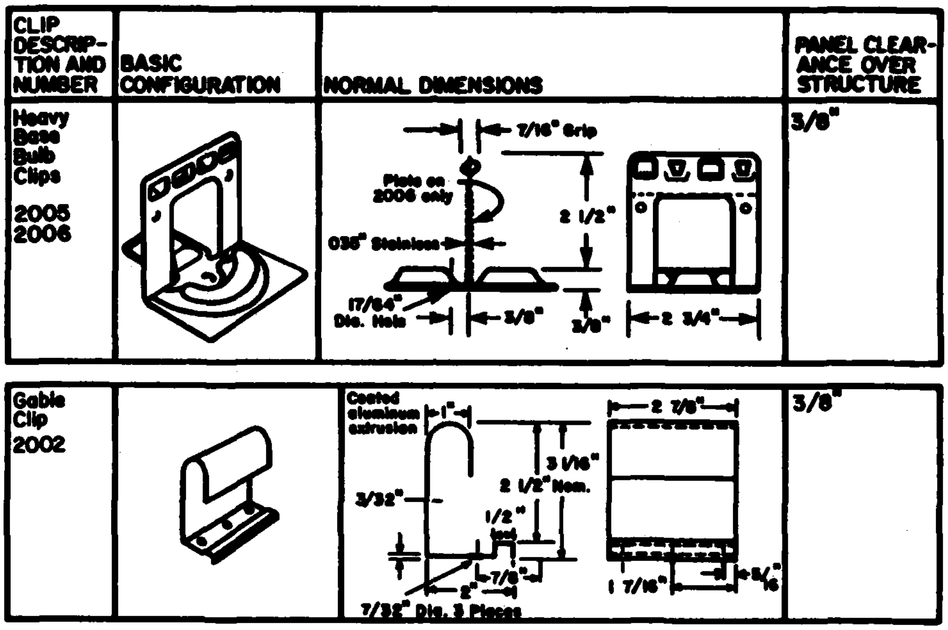

Figure 13. Panel attachment clips.

Figure 14. Counterflashing at firewall.

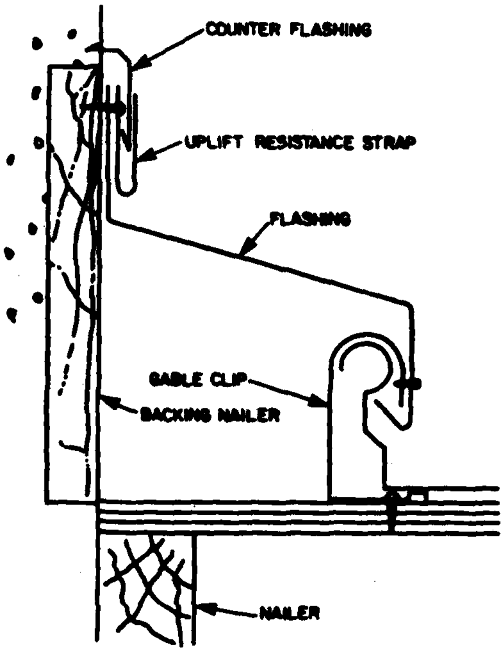

Figure 15. Flashing details at firewall.

Figure 16. Counterflashing step intersection details.

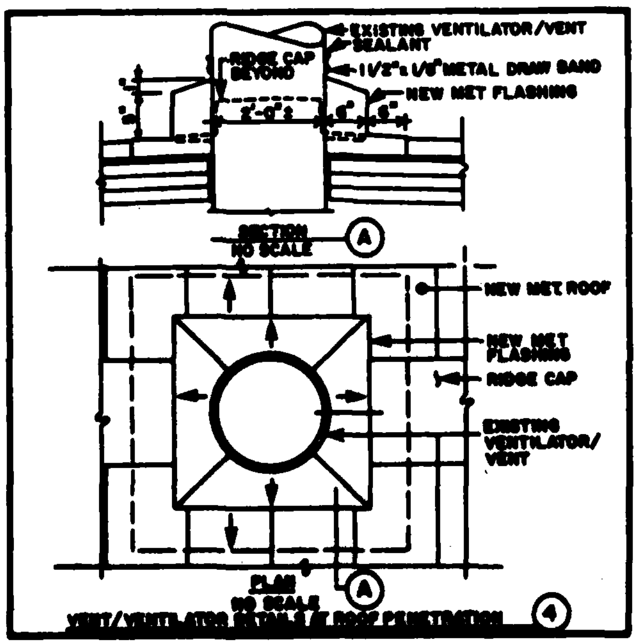

Figure 17. Detail of ventilator flashing.

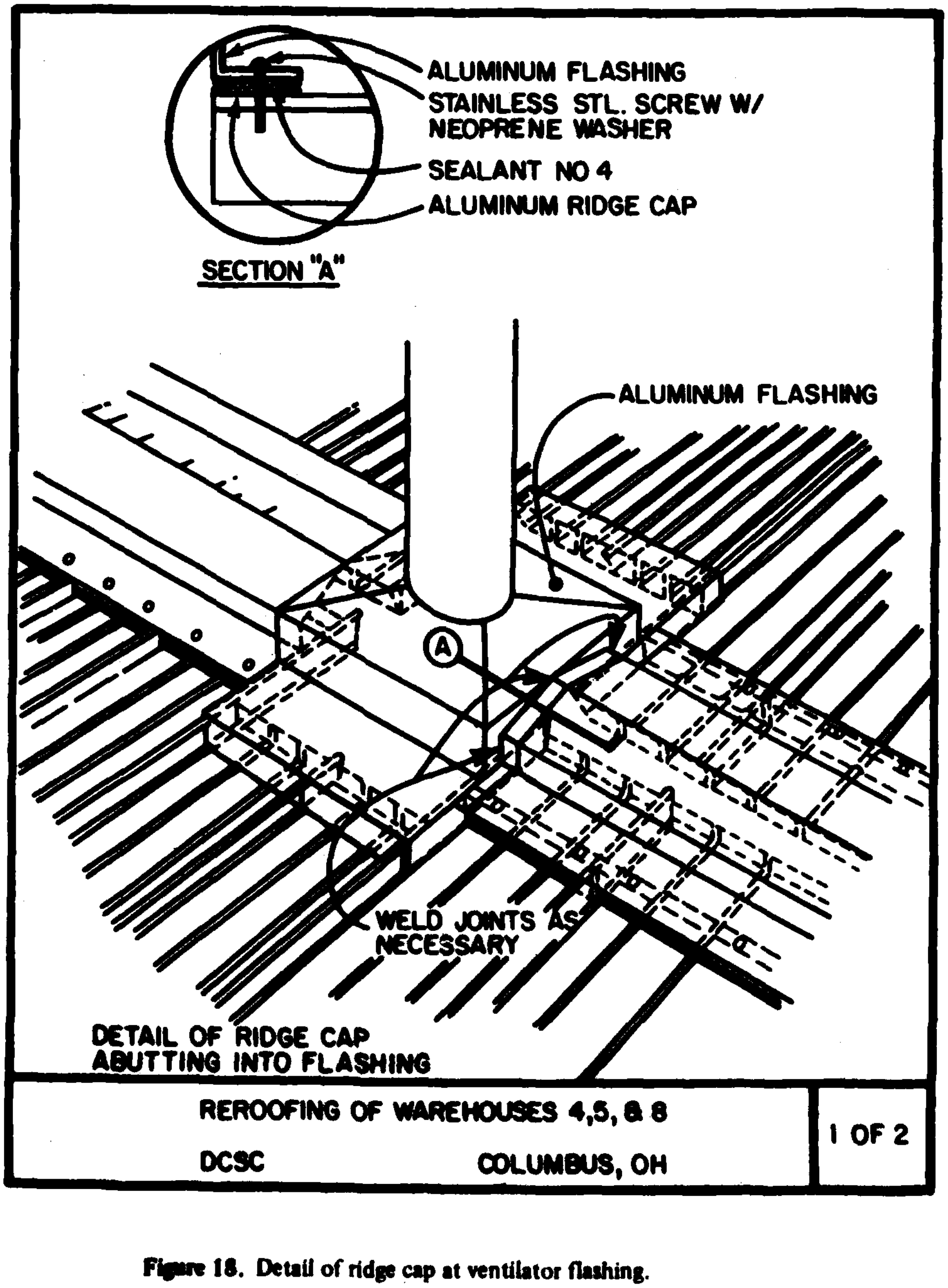

Figure 18. Detail of ridge cap at ventilator flashing.

Figure 19. Intersection of ridge cap and ventilator flashing.

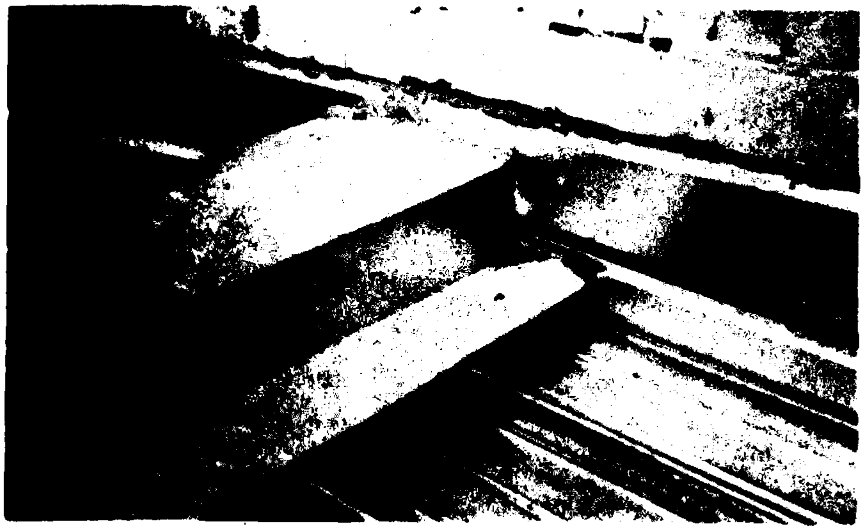

Figure 20. Peak of ridge cap close to top of counterflashing.

Figure 21. Peak of ridge cap above top of counterflashing.

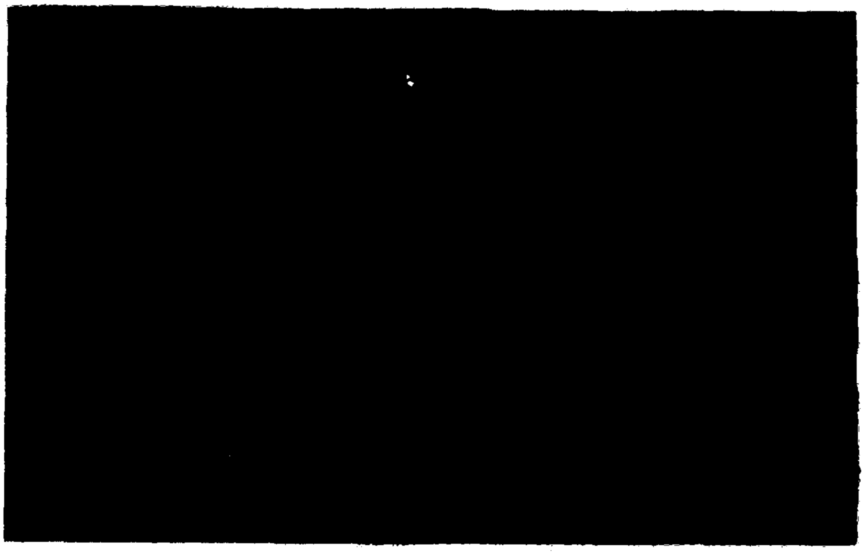

Figure 22. NBS test rack of samples for corrosion tests.

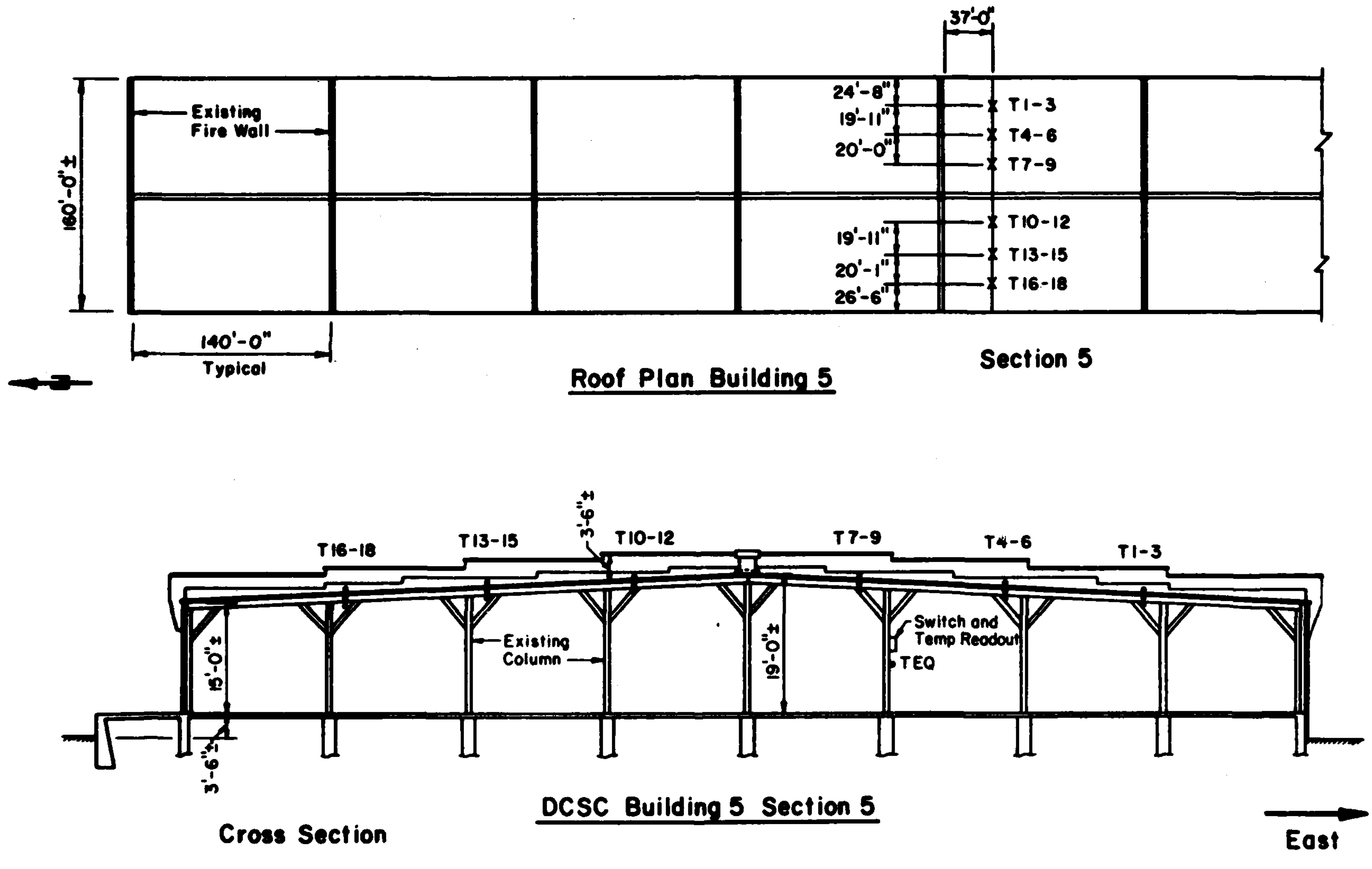

Figure 23. Cross section of Warehouse 5 showing thermocouple locations.

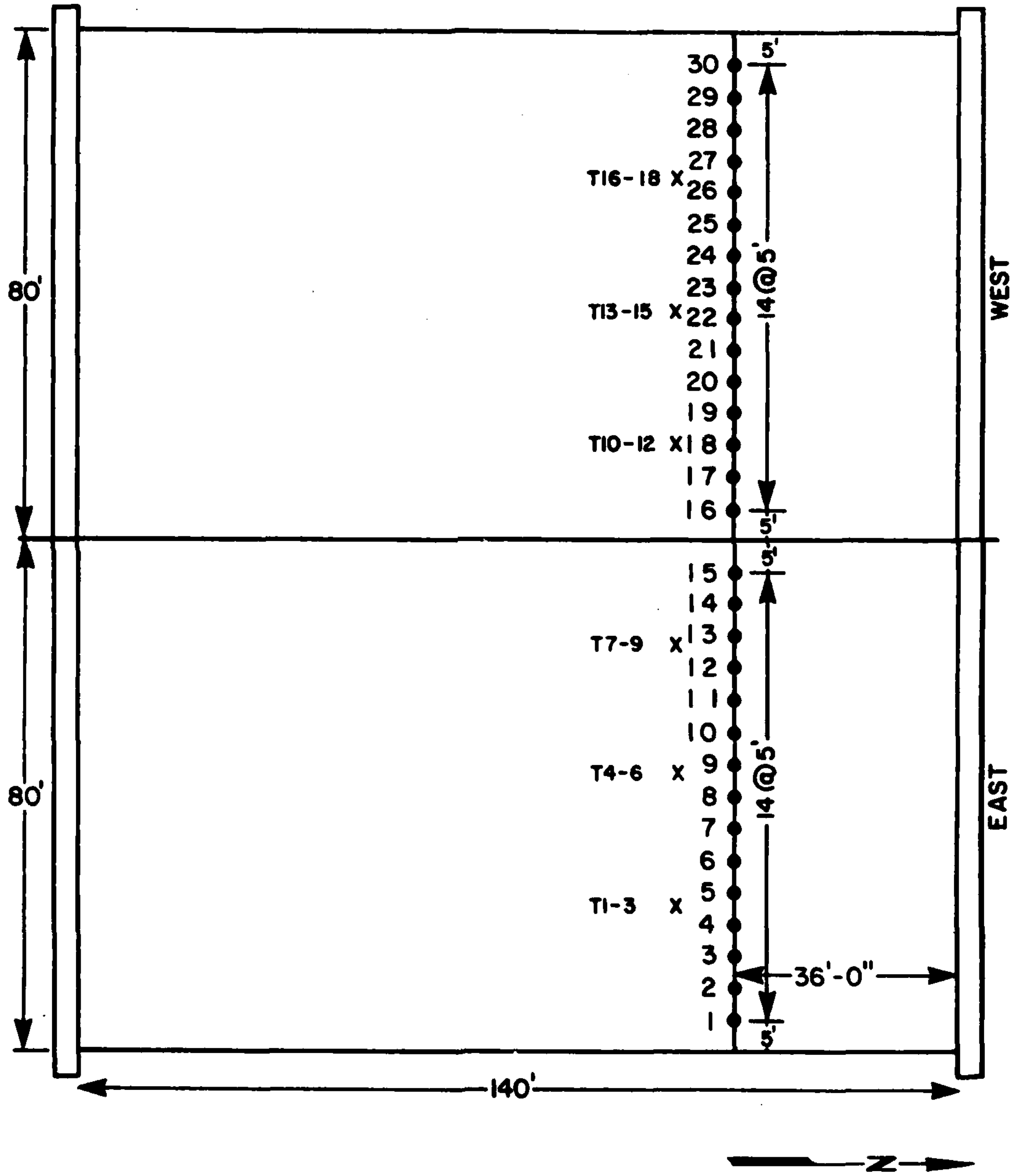

Figure 24. Arrangement of elongation and deflection measurement points.

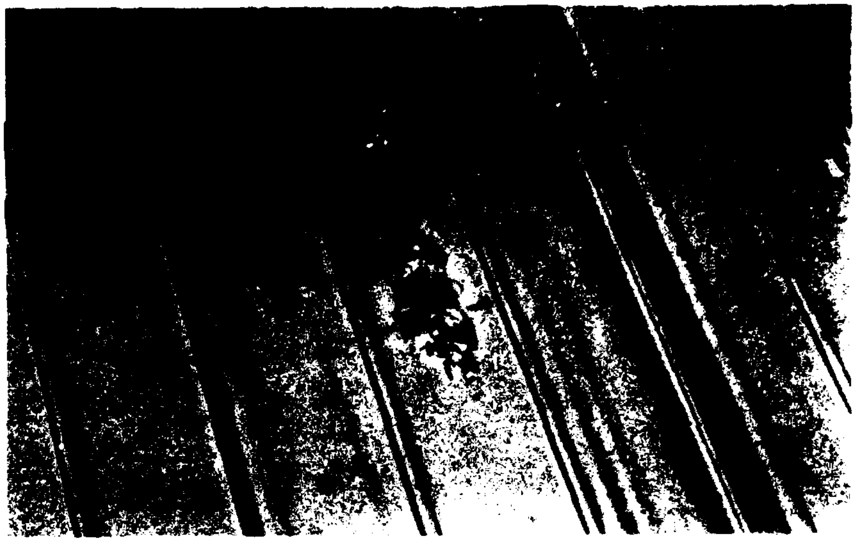

Figure 25. Typical thermocouple on aluminum panel.

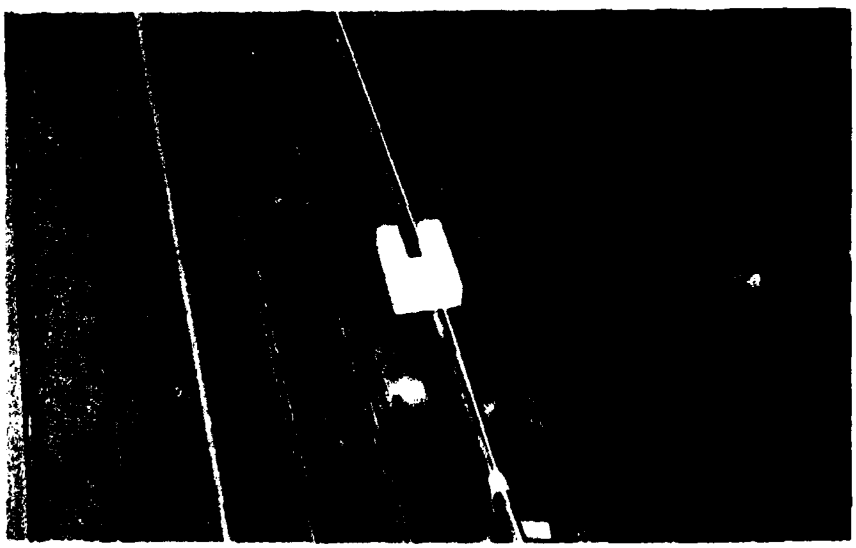

Figure 26. Typical elongation and deflection measurement point.

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